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Trends in Western Advanced Technology

National Intelligence Estimate
Volume II—The Estimate

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NIE 1-3/5-86/II
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TRENDS IN WESTERN
ADVANCED TECHNOLOGY

VOLUME II—THE ESTIMATE

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PREFACE

This Estimate is published in two volumes. Volume I is the Key Judgments. Volume II is a comprehensive discussion of trends in Western advanced technologies.

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SCOPE NOTE

This Estimate—the first by the Intelligence Community to analyze Western¹ technologies—assesses status and trends in nine high-technology areas. Assessments of current technology levels are, for the most part, based on demonstrated product performance and manufacturability as well as research achievements. Estimates of future technology levels are based on current technology status, research and development activities, and national technology resources and policy. Data on current and future market size are based on private-sector forecasts and other open source material and are not to be interpreted as intelligence assessments. Market shares and trade flows are considered where appropriate, but are not used as measures of technology capability. This Estimate concentrates on technology, which is a major component of competitiveness. Detailed assessments of the competitive implications of foreign advances in the nine technology areas are beyond the scope of this Estimate and could be the subject of a separate study. Firm conclusions on this subject would require a much more comprehensive treatment of factors other than technology that influence competitiveness. []

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Foreign technology levels in this Estimate are assessed with respect to levels in the United States. Overall assessments of European technology levels are based on the leading country in Europe rather than an average over all European countries. Technology capabilities of the newly industrializing countries (NICs), although potentially important in determining market share, will continue to be highly dependent on access to advanced technology in the developed countries. Our ability to assess and forecast foreign technology levels is limited by gaps in our information and analytic uncertainties. The Intelligence Community has concentrated its resources on a few key technologies and on those countries developing significant technological and competitive strength. Forecasts of national differences in technology levels are greatly complicated by uncertainties in the impact of government support measures and the amount of international technology diffusion. []

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DISCUSSION

Relative Positions and Trends

1. All developed countries recognize the importance of high technology, and both government and industry have programs under way to enhance their technology capabilities (see annex A: National Technology Resources and Strategies). These countries see the level of their technology as critical to their eco-

nomics competitiveness and military capability. Technology levels are increasingly important in determining overall economic success, but other factors such as innovation environment, trade policy, and macroeconomic developments are crucial in determining competitiveness and market share (see inset: Technology, Competition and Economic Impact). The technologies

Technology, Competition, and Economic Impact

Technology—and technological innovation—can be the single most important influence on competitive developments because of its decisive impact on productive capabilities. Because natural resources and other raw materials have economic significance only as a function of technical knowledge, increases in such knowledge are equivalent to an expansion of the resource base of the economy. Technological innovation has often served as a means to overcome resource scarcities by expanding enormously the number and the quality of resources that are capable of being economically exploited.

Technology capability, however, is not the only important factor in international economic competition. There are a number of dimensions, all of which need to be taken into account in assessing the relative competitive strength of firms, industries, or nations. Among these factors are:

- Corporate financial strengths and weaknesses*—the financial position of firms can determine their ability to undertake necessary investments in capital equipment and R&D, to withstand cyclical downturns, to undertake competitive marketing strategies, and to aggressively price products.
- Marketing strategy and tactics*—some firms may “target” certain overseas markets, adopting a strategy of sacrificing profit margins in hopes of gaining market share over time; firms in targeted markets that are unable or unwilling to forgo current income in response may be forced to withdraw or be absorbed.
- Capital investment levels*—especially in most high-technology industries, a minimum level of R&D activity is required in order to keep up with competitors and to react to rapid technological changes that can make equipment obsolete before its useful economic life is over.
- Financial markets and the cost of capital*—the relation between a country’s financial institutions

and manufacturers can determine how easily and cheaply its domestic firms acquire funds to finance corporate growth and expansion; the costs of such financing can confer an advantage on those firms by enabling them to undertake more and riskier investment projects than would otherwise be possible.

- Tax policies*—a number of countries adapt their tax systems to allow domestic firms to invest in capital equipment and R&D more cheaply, and to promote demand for their output.
- Industrial policies and “targeting”*—the extent to which governments are willing to support key sectors can influence the state of international competition involving certain critical or rapidly advancing technologies.
- Regulation of competition*—some governments adapt antitrust and other regulatory policies to allow cooperation among rival firms and to exclude foreign competition, in order to organize or “rationalize” production among the domestic industry’s largest or most efficient producers.
- International macroeconomics and exchange rates*—monetary and fiscal policies adopted by governments (and their “mix” relative to those in other countries) can shape the competitive environment by influencing interest rates, levels of inflation, and exchange rates, as well as international capital flows.
- Competitive strategies*—apart from marketing strategies adopted by individual firms, the state of international competition in a number of key sectors is determined by the process of governments and industries in several countries making interdependent competitive decisions; the interplay of these competitive strategies may lead either to retaliation or to cooperation from foreign rivals.

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assessed in this Estimate also have increasingly important military applications, but the level of technology incorporated into military systems is only one of several factors contributing to system effectiveness. [REDACTED]

2. The nine technology areas treated in this Estimate are broad, and many of them are interdependent. Semiconductors and advanced structural materials, for example, affect many sectors, and boundaries between telecommunications and data processing are becoming increasingly blurred. Machine tools and robotics technologies are even more pervasive because they impact all manufacturing activities. The following sections summarize foreign status and trends in capability in nine technology sectors. General economic and military impacts are discussed, but detailed assessments of how technology translates into future world market share or military capability is beyond the scope of this Estimate. [REDACTED]

Semiconductors

3. The semiconductor industry is a small, but vitally important piece of the electronics industry. Semiconductors, particularly integrated circuits (ICs) are used in almost all industrial sectors to increase the performance, capability, and reliability of a large number of products. Total worldwide semiconductor consumption has grown from \$4.4 billion in 1975 to \$28.7 billion in 1984, and industry observers forecast a market of about \$160 billion by 1995. Although the semiconductor industry is a sizable and growing industry in itself, the most important aspect of semiconductor technology is its contribution to other civil and defense industries. [REDACTED]

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² We have taken the technical capabilities of US captive suppliers (such as IBM and AT&T that produce semiconductors for their own use) into account when comparing foreign developments with those of the United States. [REDACTED]

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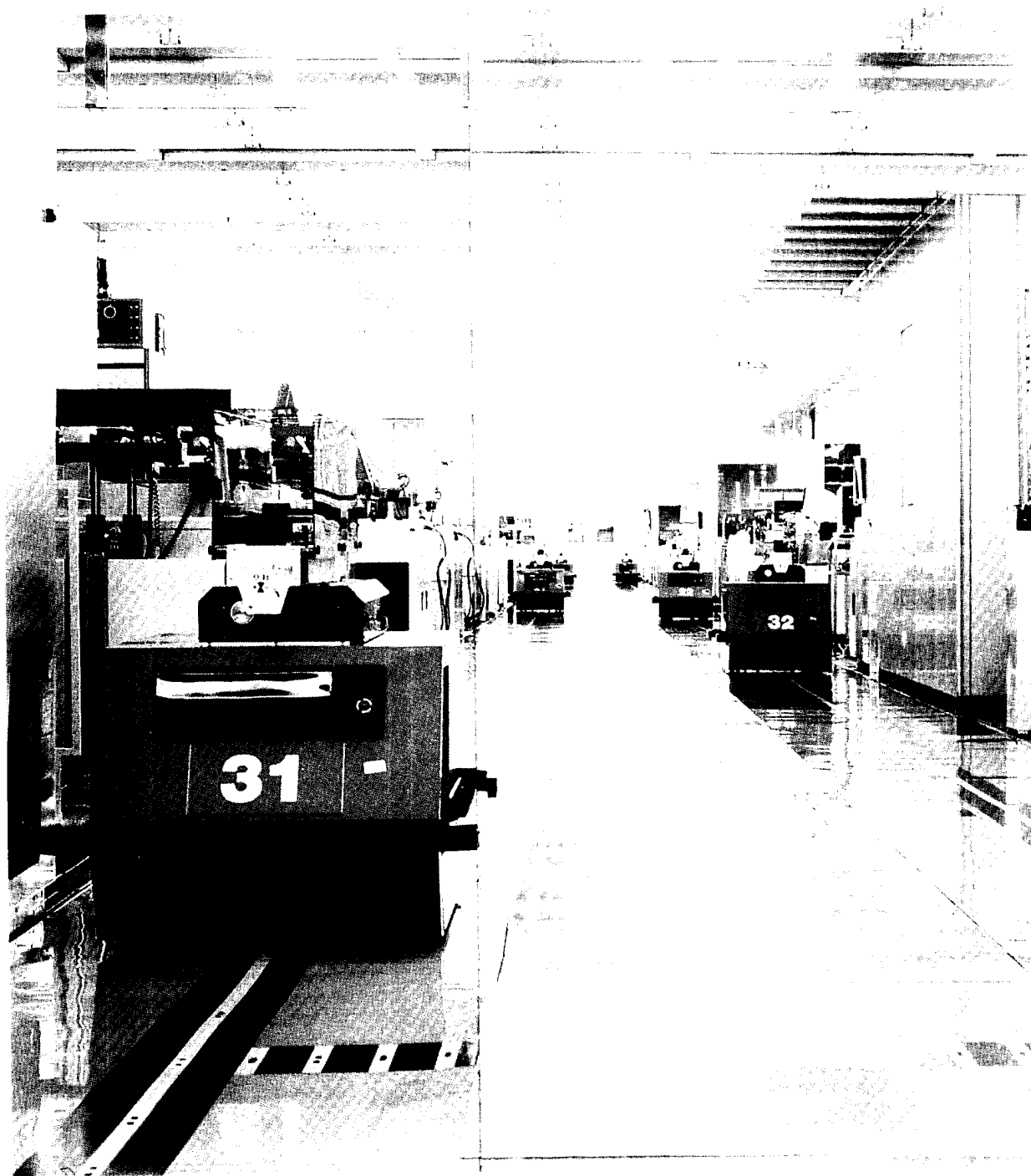


Figure 3. The degree of automation at the Saijo facility—unprecedented in the semiconductor industry—is made possible by special Mitsubishi-designed robots that transport wafer cassettes through the production process. Foreign access to this leading-edge facility has been extremely limited.

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Data Processing

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20. Worldwide revenues of the top 100 data-processing (DP) firms were about \$130 billion in 1984, and most forecasters are calling for a market over \$300 billion by the mid-1990s. Sales of computers currently comprise about 40 percent of the DP market, with mainframe sales about equal to the combined sales of minicomputers and microcomputers. Peripheral equipment³ now accounts for about one-third of all data-processing sales. Software—currently only about 10 percent of the market—is the most rapidly growing segment, and some experts believe it could account for almost a fourth of total DP sales in the mid-1990s.

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21. IBM currently dominates the market, with about one-third of all sales. Of the top 20 data-processing firms, the Japanese firms Fujitsu (ranked sixth), NEC (ranked ninth), and Hitachi (ranked 12th) are among the fastest growing in total sales; and the European firms, with the exception of Siemens (Germany), are among the slowest (see table 2). Revenues of Japanese computer firms could surpass those of several traditional US mainframe suppliers within the next several years.

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³ In this Estimate computer peripheral equipment includes data storage units (magnetic and optical) and input/output devices (printers, readers, and terminals).

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Figure 4
Data Processing: Technology Status/Trends,
Position Relative to the United States

Japan / Europe

▶ Improving ● Maintaining ◀ Declining	Lag			Parity With US	Lead		
	Sub- stantial	Clear	Slight		Slight	Clear	Sub- stantial
Supercomputers							
Components		◀				▶	
Packaging/cooling	◀	▶					
Architecture		●	▶				
System software		● ^a	▶				
Applications software	○		●				
General purpose systems							
Components		◀				○	
Packaging/cooling	◀		▶				
Architecture		● ^a	○				
System software		◐ ^a					
Applications software		○ ^a	● ^a				
Minicomputers microcomputers							
Hardware			◐ ^a _a				
Software		○	● ^a				
Peripherals							
Storage							
Magnetic	● ^a			○			
Optical						◐	
Printers							
Impact		● ^a				○ ^a	
Nonimpact		● ^a		○ ^a			
Terminals							
Dumb			● ^a			○ ^a	
Intelligent			◐ ^a _a				

^a Estimate based on limited data/analysis.

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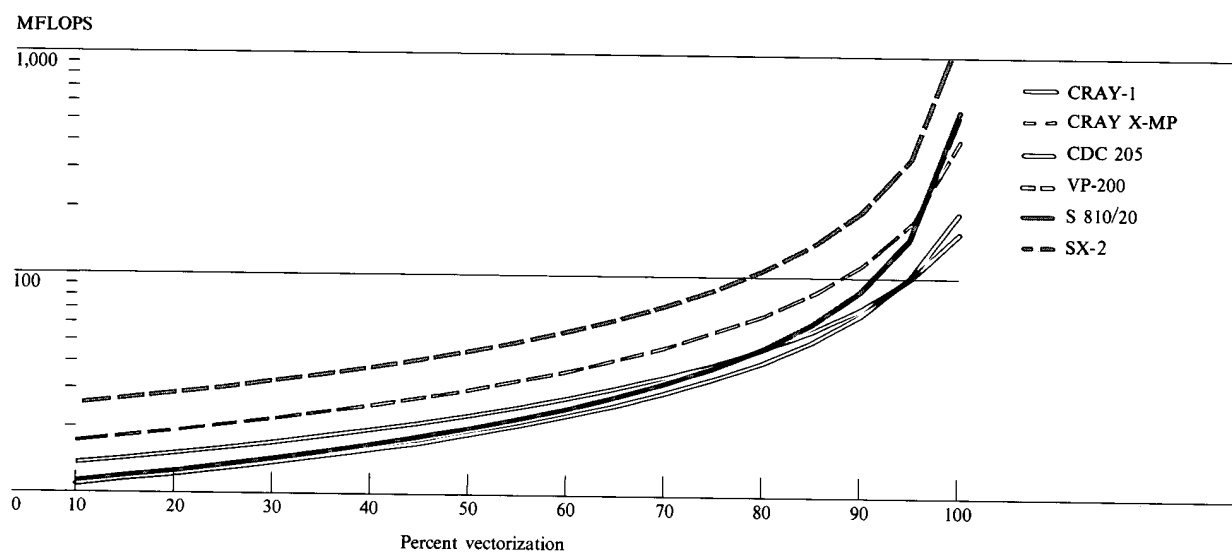
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Figure 6
Supercomputer Performance



High energy physics

Linear programming

Load flow, CAD

Circuit design, reservoir modeling

Thermonuclear, atmospheric physics-radiation

Structural design

Seismic, image processing

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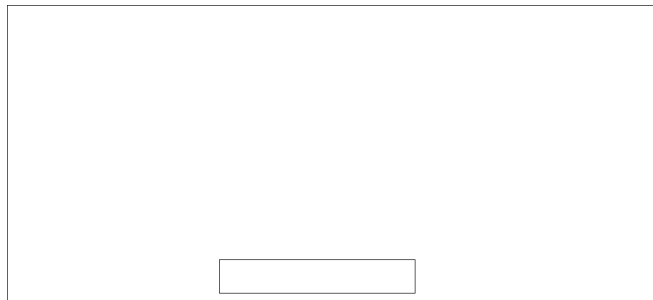
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31. **Optical Storage.** Optical storage is the only major area in which foreign technology currently leads the best available US technology, and it is an area of potentially high civil and military significance. Optical storage can be divided into two main groupings—write once and erasable systems. Optical storage offers much more storage capability than conventional techniques and is inherently better suited for use in extreme environments.

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Telecommunications

42. The telecommunications industry is undergoing one of the most rapid and extensive periods of change in its history. The industry is modifying employment patterns, consolidating equipment offerings, and requiring increased R&D and capital investment. The primary technological driving forces behind these changes are advances in semiconductors and software that are key technologies for both the communications and computer industries. The functional differences between these two industries' technologies, products, and applications are shrinking rapidly. Both industries are competing to offer a full line of office automation equipment, advanced business systems, and enhanced network services. Efforts to combine microelectronics, computer, and communications capabilities into a single entity are resulting in corporate acquisitions, mergers, alliances, and reorganizations. Most governments are also instituting policies that will have a critical impact on technological capabilities. Political and economic pressures are opening up new markets through liberalization policies and, as a result, the monopolistic alliances between some governments and their principal equipment suppliers are breaking down.

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⁴ Microcode is a sequence of elementary steps called micro-operations that organize and control registers, logic circuits, and data paths to carry out a specific machine language instruction, such as adding or logical comparison. Each machine instruction has its own unique sequence, called a microprogram.

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Manufacturing: Machine Tools/Robotics

74. Advances in microelectronics have led to a new generation of highly automated, general purpose machine tools with dramatically increased capabilities for commercial and military industrial production (see inset: The Revolution in the Machine Tool Industry). Metalworking industries, including automobiles, aerospace, and shipbuilding are particularly dependent on the machine tool sector, but almost every manufactured product is made on machine tools or on machines that have been built by machine tools. Total world production of machine tools was about \$21 billion last year; forecasts for 1995 are about \$50 billion.

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75. In contrast to machine tools, the robotics industry is new, and the impact of robotics on national economies is still comparatively slight; worldwide production last year was only \$1.2 billion. The potential, however, is great; in addition to substituting for human labor, robots allow flexibility in automating manufacturing processes that, when combined with computers and numerically controlled (NC) machine tools, can sharply boost productivity. Moreover, robots' flexibility and reprogrammability features facilitate their use in automated systems for small-batch production; about 70 percent of manufacturing operations are now batch jobs.

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The Revolution in the Machine Tool Industry

Machine tools, according to the National Machine Tool Builders Association, are power-driven machines, not supported in the hands of an operator when in use, which shape or form metal by any combination of cutting, impact, pressure, or electrical techniques. Machine tools include lathes, drill presses, machining centers, grinding machines, and forging presses. (u)

Machine tools are differentiated as numerically controlled types and standard or manual machines. Numerically controlled machines are equipped with a control system that operates the machine by numerically coded programs fed into the system as punched tape or by playback of prerecorded operating programs. In computer numerically controlled systems, the control is based on a microprocessor. Standard machines are controlled by an operator. [REDACTED]

The application of microprocessors is reducing the cost and increasing the reliability of machine control systems. The application of microelectronics technology is also sharply increasing the versatility of machines. One stage in the development of numerically controlled systems—known as direct numerical control—uses a computer to direct the motions and operations of up to a hundred machine tools simultaneously. [REDACTED]

The machining center, with an automatic tool changer, is one of the significant outgrowths of numerical control. It is a multipurpose machine programed to do several operations, such as turning, boring, milling, drilling, and tapping, without repositioning the part. On the basis of these capabilities, machining centers are becoming the nucleus of a completely integrated parts manufacturing system known as a flexible manufacturing system. These systems embrace machining operations, assembly, and in-process inspection, using computers to control individual operations and aiming at the ultimate goal of a fully automated, unmanned factory. [REDACTED]

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⁹ According to a recent industry survey, the Japanese share of the world robot population stands at 65 percent, compared with 13 percent for the United States and 19 percent for Western Europe.

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Figure 12
Manufacturing: Technology Status/Trends
Position Relative to the United States

Japan/Europe

	<div> <div>▶ Improving</div> <div>● Maintaining</div> <div>◀ Declining</div> </div>	<div> <div>Lag</div> <div>Sub-</div> <div>stantial</div> </div>	<div> <div>Clear</div> </div>	<div> <div>Slight</div> </div>	<div> <div>Parity</div> <div>With</div> <div>US</div> </div>	<div> <div>Lead</div> </div>	<div> <div>Slight</div> </div>	<div> <div>Clear</div> </div>	<div> <div>Sub-</div> <div>stantial</div> </div>
Machine tools									
Control	●							○	
NC/CNC	●							○	
Sensors	○							●	
Interfacing				● ^a					
Structure							●	○	
Cutting				▶	●				
Forming					○		●		
Supporting elements				○	▶				
Robotics									
Mechanical					●			○	
Control							● ^a		
Language				○	●				
Interfacing					●				
Sensors									
Vision				● ^a					
Others					●		○ ^a		

^a Estimate based on limited data/analysis.

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